

There is little doubt that the bulk of the organic matter in meteorites is indigenous, judging from isotopic measurements on C, H, and S (20, 21). Such proof is not available for individual compounds, however, and it is therefore necessary to resort to less direct arguments to rule out terrestrial contamination. We shall briefly review the most reliably established features of organic matter in meteorites, and see how well FIT reactions can account for them. Owing to space limitations, we can only give a concise summary of the most pertinent data. The interested reader may wish to consult the original sources, as well as the reviews of Hayes (22), Vdovykin (23), and Oró and co-workers (24).

Heavy alkanes. The same few compounds dominate in meteoritic and FIT hydrocarbons (18, 25, 26). Normal (straight-chain) hydrocarbons are most prominent (Fig. 2), followed by five slightly branched (monomethyl and dimethyl) isomers (27). This resemblance is highly significant if one considers that some 10^4 structural isomers exist for saturated hydrocarbons with 16 carbon atoms. Apparently the meteoritic hydrocarbons were made by FIT reactions, or a process of the same extraordinary selectivity. The Miller-Urey reaction, incidentally, shows no such selectivity. Gas chromatograms of spark discharge hydrocarbons show no structure (13). Apparently all 10^4 possible isomers are made in comparable yield, as expected for random recombination of free radicals.

The indigenous nature of the alkanes in at least the Murray, Murchison, and Orgueil meteorites (18) is supported by four lines of evidence: absence of the isoprenoids pristane and phytane (18), which occur in nearly all terrestrial hydrocarbons (13, 26, 28); characteristic light hydrocarbon pattern (18); consistently low abundance of alkanes in the C3 chondrite Allende (18, 29), which is metamorphosed and hence may be regarded as a blank; and carbon isotope data (21, 30).

Most of the remaining compounds in the meteoritic chromatogram (acenaphthene, alkylbenzenes, olefins) can be made by FIT syntheses under appropriate conditions (18). Kvenvolden *et al.* (30) and Oró *et al.* (31) had reported alicyclic hydrocarbons in the Murchison meteorite on the basis of low-resolution chromatograms. These

compounds were not confirmed at higher resolution (18), however, but can, in any event, be made in the FIT synthesis. The authors have found large amounts of cycloalkanes in a commercial Fischer-Tropsch sample.

Carbon isotope fractionations. Meteorites show a very large difference in $^{12}\text{C}/^{13}\text{C}$ ratio between carbonate and organic carbon: 60 to 80 per mil (20, 21, 32). This trend remained unexplained for a number of years, because coexisting carbonate and organic matter on the earth shows a much smaller difference, typically 25 to 30

proposed that the two types of carbon came from two unrelated reservoirs while Arrhenius and Alfvén (33) suggested fractionation during carbonate growth from the gas phase, involving multiple desorption or metastable molecules.

It turns out, however, that the Fischer-Tropsch reaction gives an isotopic fractionation of just the right sign and magnitude, owing to a kinetic isotopic effect (34, 35). From the temperature dependence of the fractionation between 375° and 550°K, the observed fractionations in C1 and C2 chondrites

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